Perspectives in hindsight

Prof. dr *ir.* Rudy Rabbinge

Farewell address upon retiring as University Professor of Sustainable Development & Food Security at Wageningen University on 24 November 2011

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Mr Rector Magnificus, ladies and gentlemen,

Science describes, analyses, predicts, explores and designs. In this way it delivers overview, insight, expectations, perspectives, utopia and dystopia and helps to prevent myopia. In addition to these roles the technical engineering sciences also construct, implement and guide interventions and change. During my long scientific career and service to university and society I have been privileged to contribute to all these tasks. In the next 45 minutes I will try to illustrate this and to make clear how important the role of science is as an honest broker in the scientific and societal debates and policy making. I will also try to make clear how wonderful it is to have the opportunity to perform these scientific tasks and to be confronted with new insights, better understanding and gloomy perspectives, but also with doomy dystopia. And even most rewarding, to offer perspectives and guide implementation and change to participate in societal evolution and contribute to sustainable development and food security.

To describe natural phenomena in the non-living and living world in the most sober and effective way, science is making use of mathematics (Leffelaar, 1993). The famous law of gravity, allegedly based on Newton's observation with the falling apple (Cohen & Whitman, 1999), is a simple formula expressing the attraction between two bodies, from which the earlier laws of Kepler on the movement of planets can be mathematically derived (Aiton, Duncan, & Field, 1997).

In his inaugural address in 1992 my friend and colleague Jan Goudriaan made clear how important accurate and generally accepted descriptions of phenomena are (Goudriaan, 1993). A good description may lead to accurate predictions when circumstances remain the same. In the physical and chemical sciences we can make ample use of accurate descriptions, but this is much more difficult in living systems where the circumstances are changing and various feedback mechanisms may occur. This fact complicates the role of the biologist and the agriculturist.

Physical characteristics such as the geometry of crops may help to describe the interception and absorption of radiation from the sun. These formulae do not only describe but may also predict whether the crop traits are known.

As early as 1964 my predecessor in Theoretical Production Ecology, Professor C.T. de Wit, showed in his standard work 'Photosynthesis of leaf canopies' (de Wit, 1964), how powerful this description is as a basis for the understanding of photosynthesis of crops in comparison with individual plants. The physical, photochemical and biochemical and physiological process in plants can be described in much detail and are then used to compute or rather to simulate the photosynthesis at crop level and on that basis the growth of canopies.

A good description of the basic physical, chemical and biochemical processes is crucial here. The integration of these descriptions will help the biologist and agronomist to understand and simulate the performance of crops (Fig. 1). The basic principles of production ecology are based on that insight and understanding. The use of physical laws such as those for the gas exchange, for the diffusion processes and for the photochemical and biochemical pathways have enabled the accurate simulation of crop growth under potential circumstances. Incoming radiation and crop characteristics, geometrical, optical, phenological and physiological, determine what is possible in principle. Of course the assumption of optimal circumstances, absence of pests and diseases, no competition with weeds and abundant availability of water and nutrients is almost never correct. Yet the models focused on these elementary physical and bio-chemical processes can compute potential yield. That may be considered a futile exercise, but the simple fact that the combination of description of the basic processes can be used to see what may be possible, has opened new insights. The theoretical computations of potential crop yields in the sixties were at the time criticized by many agriculturists and labeled as a world of dreams that would never become reality. However, we now see that the average yield of wheat in the Netherlands is not far below its present potential, which demonstrates that within a period of only 40 years, the impossible has become reality (Fig. 2). This could be achieved by a clear analysis of the crop growth limiting (nutrients and water) and crop growth reducing factors (pests and diseases). A clear analysis of the way basic processes are affected such as the uptake of ions by the root system, the coverage of leaves hindering light penetration and absorption through molds on the leaves and many, many other mechanisms have helped to explain growth reduction or growth limitation. The understanding of the way the basic physical, bio-chemical and physiological processes are affected will also help to determine how much this means in terms of yield reduction.

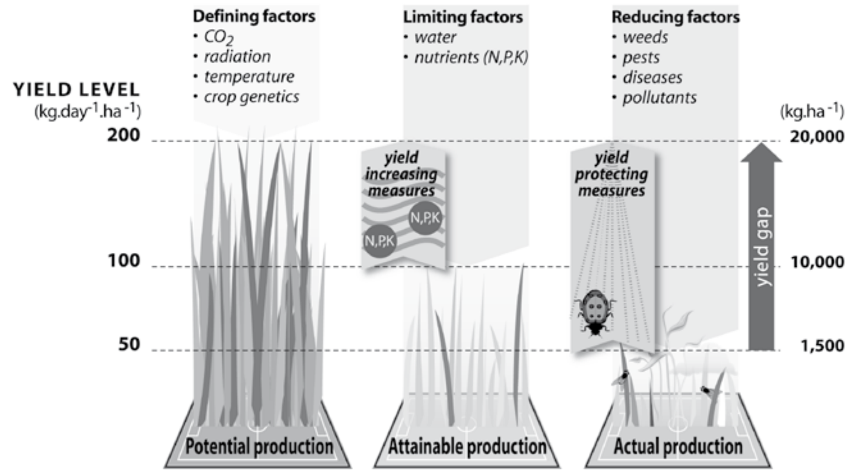

Figure 1 Classification of production situations with corresponding yield levels and associated agricultural measures to close yield gaps (Bindraban, Rabbinge, & Lövenstein, 2012)

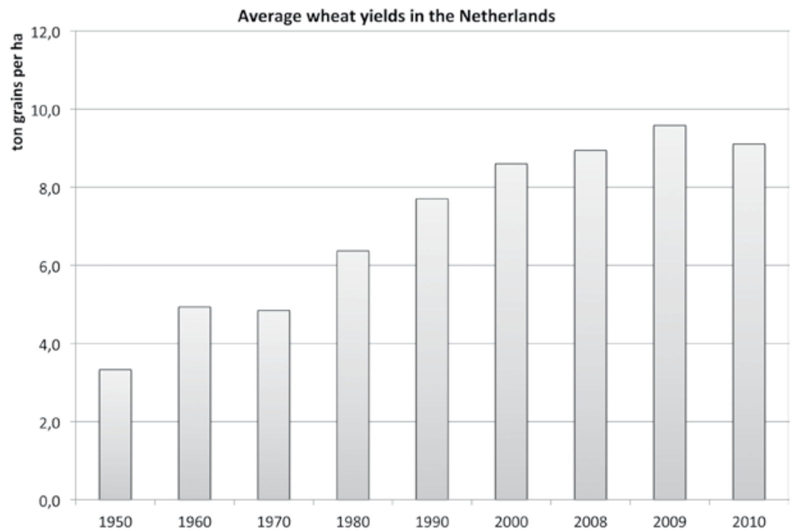

Figure 2 Winter wheat yields in tons per hectare as realized in the Netherlands since 1950 (CBS, 2011)

In my inaugural address in 1985 (Rabbinge, De brugfunctie van de gewasecologie, 1985), I made clear that the role of the crop ecologist and theoretical production ecologist is to bridge aggregation or integration levels and to enrich the possibility to understand and explain (Fig. 3). It is possible to understand the growth of plants and crops under different circumstances and this fact lays the basis for management of crops not on the basis of long term empirical experience alone, but merely on the basis of insight in the functioning of the system.

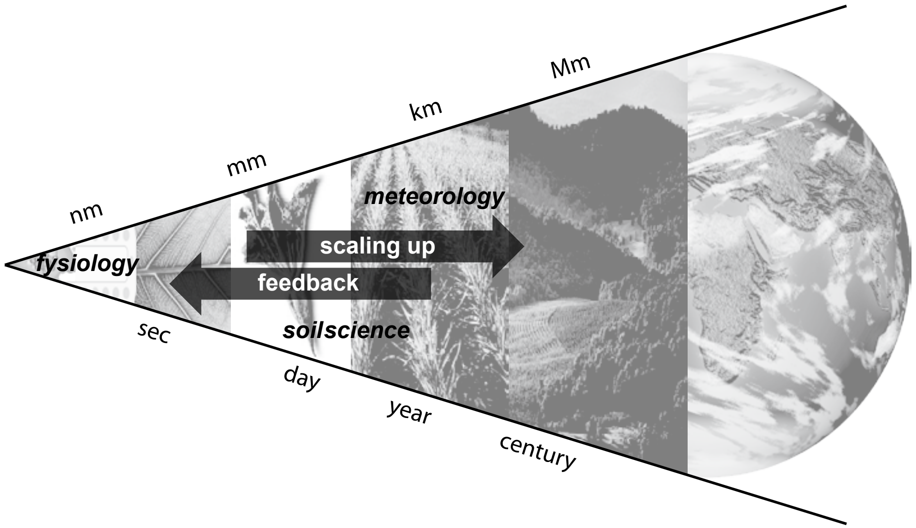

Figure 3 Aggregation levels in time and space indicating the various scientific domains, integrated within crop ecology to deepen insight and widen perspectives in explorative studies. Adapted from (Goudriaan, 1993)

Of course things are not ideal and it is for that reason that simulation and experimentation on explanatory process level and also on explaining level are combined, in other words no simulation without experimentation. This slogan of the former department of Theoretical Production Ecology stated some 40 years ago is still valid. The achievements in TPE during the 30 years of its existence, 1968-1998, in terms of scientific outputs and outcomes over these years have been impressive and I feel very privileged to have been the leader of the group for nearly two thirds of that period. In that period about 100 PhD's, some 500 MSc's and a numerous number of publications, courses, training programs and workshops have been achieved.

The four themes in which we were active, have seen considerable change and progress. Theme 1: potential growth and development; theme 2: limiting factors, nutrients and water; theme 3: reducing factors, pests, diseases, weeds, pollutions and theme 4: production systems at higher spatio-temporal scale levels.
The first theme, plant and crop growth, has been well understood in terms of assimilation, respiration and accumulation of dry matter but it is still poorly understood in terms of developmental phases and functioning. Recently, colleagues in biochemistry and molecular biology made considerable progress in the understanding of the processes that determine the patterns of development and as such the phenology in reaction to environmental conditions and how it is predetermined by the genetic traits (Kaufmann, Smaczniak, Vries, Angenent, & Karlova, 2011). It will be possible in due course not only to understand and explain growth under well-defined conditions, but also to understand the feedback from plant development. Plant development in particular requires more than integration of physical and bio-chemical processes, it requires an understanding of the purposive phenomena which are a result of evolutionary processes. Approaching biological functioning as if being purposeful is fundamental in biology and in fact the power of evolutionary biology. Flowering of rye is not only determined by temperature or temperature sums but also by day length, as a strategy to yield and survive under harsh conditions (van Dobben, 1962). The background of such phenomena is partly based on this understanding of pseudo-teleology. It is the intellect and insight of the biologist to identify and explain such phenomena on the basis of evolutionary principles.

Within the first theme, basic processes concerning stomatal behavior and the role in transpiration and evaporation have also been elucidated, thereby contributing to C-balance studies. It is striking to see that the general belief that tropical rain forests are the lungs of the world is not justified and that grasslands with their mechanism of underground storage in the root zone with very low maintenance respiration are of much more importance than the forests (Dirks, 2012). The grassland biomes cover 30% of terrestrial systems and are a better explanation for the C-gap in the C-balance than a more active ocean. It is amazing to see that such insights are less generally accepted than preconceived ideas or prejudices. Such C-balance studies are of critical importance for all research in global environmental change.

In the second theme, the resource use efficiency in macro and micro nutrients and use of water in crop growth is explained with elaborated models, laying the basis for optimization of the use of inputs. This helps to attain maximal resource use efficiency including water. Depending on the context and the characteristics of crops be it well-endowed, endowed or less endowed soils, the optimum for use of external inputs such as fertilizers is different (Fig. 4). At well-endowed soils the optimum use is near the potential growth level. This is against intuition but at less endowed soils the optimum is much more variable and in many cases less near to the potential, due to the many investments needed for upgrading the productivity. Again this is a phenomenon that is difficult to unravel with analysis at the crop level alone, it requires the integration from the various processes through models to understand these phenomena. Synergism emerges between improved conditions, which is counterintuitive. The lower GHG-emission in highly productive rice systems in comparison with less productive situations is an example of such a phenomenon as has been demonstrated by colleagues Van Breemen and Kropff (Denier Van Der Gon, et al., 2002).

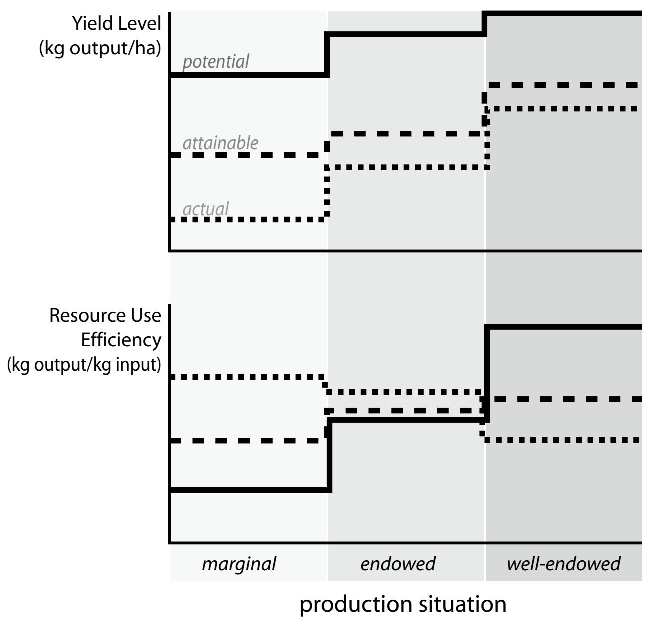

Figure 4 Yield levels and associated resource use efficiency under marginal, endowed and well-endowed production situations

The way precision agriculture making use of GPS systems is now managing fields in such a way that heterogeneity is not a liability but an asset leading to very high efficiencies of use of natural resources, is again an illustration of the advantage of working at different aggregation levels. Aggregation over levels of understanding, but also aggregating in spatial scales is possible when done with care.

In the third theme of the former TPE group, crop growth reducing factors were studied, among which weeds, population dynamics of pest species, disease causing organisms, including their natural enemies and competitors. Again the basic processes in this case of population dynamics and of the relation between various organisms in behavioral studies have to be quantified to be able to do simulations at higher integration levels (Rabbinge, De brugfunctie van de gewasecologie, 1985). By coupling to crop growth models, dynamic and well-documented thresholds were derived that could be used in practice.

Numerous studies in this field have delivered promising results, which are now widely applied. Here the role of the production ecologist is already more than description and analysis alone; he/she contributes to the development of management support systems by coupling models for population dynamics and crop growth. Models of a summary nature are often used to develop management strategies based on field observations and reliable predictions.

The development of flexible damage thresholds is based on such combined models and is used in various cropping systems. Again that way of working has led to the so dearly needed fine-tuning of context and circumstance dependent thresholds that cannot be derived directly from observations at systems level, as it would require a prohibitive number of experiments.

The fourth and last theme concerns the higher integration levels where the three themes are combined and are used to perform more explorative than explanatory studies to see what is possible under which conditions. Here the connection with socio economic studies is vital (Fig. 5). The nature of the studies in theme 4 was traditionally very different from the first three themes. I will elaborate this later in this talk. I will now summarize and evaluate the role of the former TPE as a new way of doing plant and animal science and agronomy. The presence of a unifying concept, the potential, attainable and actual production level, the use of a unifying methodology, explanatory, summary, predictive and exploratory models and the acceptance of a unifying systems approach were vital for the core of the graduate school. It is striking to see that the graduate school is now flourishing although the unifying concepts are less visible nowadays, but the impact of the school is very impressive worldwide. The role of the various directors has always been very stimulating and the training in T-shaped skills (Fig. 6) introduced by colleague Johan Bouma (Bouma, 1997), is very useful for an academic training for both specialist and general insight. It has made a considerable difference as has been demonstrated in many reviews and evaluations during the last decade.

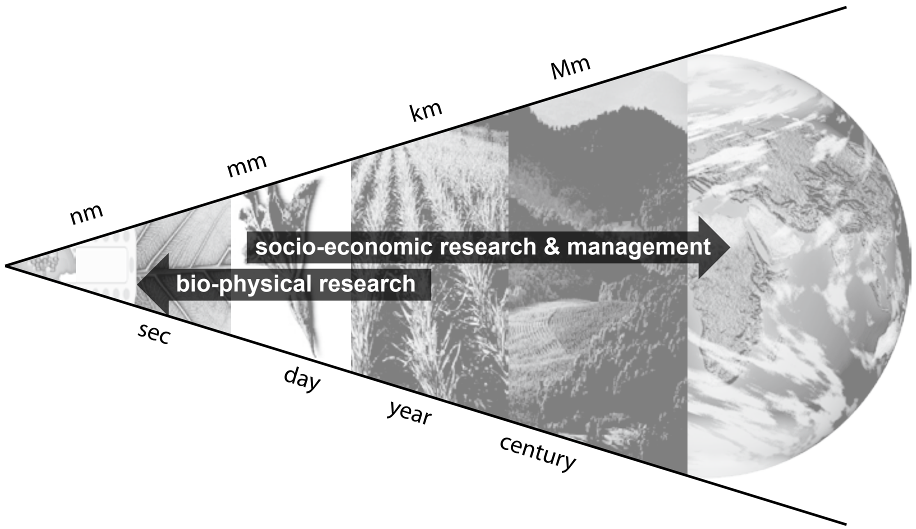

Figure 5 Trans disciplinary field of crop ecology as bridge function between bio-physics and socio-economics. Adapted from (Goudriaan, 1993)

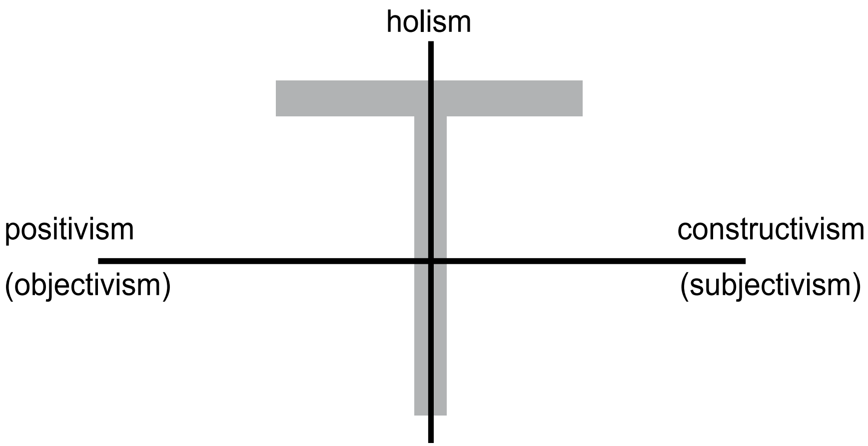

Figure 6 T-shaped skills as implemented in the education programmes of Wageningen University (Bouma, 1997)

There are also considerable spin-offs of the approach propagated by TPE. The concept of bio-solar cells using the first step in the photosynthesis, the photochemical process at the thylakoid membrane, in isolation to harvest the incoming radiation without turning it into plant dry matter or even worse ethanol, and instead using it immediately as an energy source is very promising and stimulating as a research challenge where various research groups are now active (Fig. 7).

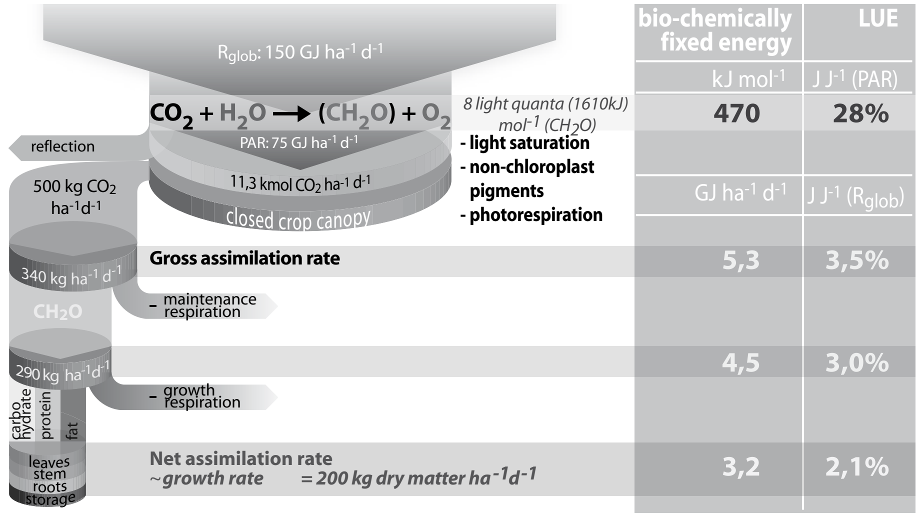

Figure 7 Changes in Light Use Efficiency along the various stages in dry matter formation within a plant (Bindraban, Rabbinge, & Lövenstein, 2012)

The willingness of many scientists from various universities and also from private companies to work together in this field is a good illustration of the way fundamental research can be directly connected to the engineering sciences that may deliver promising future energy systems. In the Biosolar cells program the high efficiency of the photochemical process is used to harvest sun energy and the synthesis of plant products that will result in much lower efficiencies is not introduced, and the even worse transformation into ethanol not taken. The consequences for land use are enormous, not 4- or 5-fold but 1000 times more area is needed for ethanol production with plants under optimal conditions than for biosolar cells using artificial leaves to fulfill a substantial energy demand (Fig. 8).

Europe in 2050: 650 million people require 2TW power

Efficiency of solar conversion	Surface per capita	Total area needed	
100 %	30 m^2	0,5 x Netherlands	artificial leaf
10 %	300 m^2	0,5 x Sweden	algae
1 %	3000 m^2	3 x France	plants
0.4 %	7500 m^2	≈ EU	bio fuel

Figure 8 Meeting energy demand by the European Community in 2050 by harvesting solar energy using various production techniques with characteristic Light Use Efficiencies and corresponding light intercepting acreage. Adapted from (de Groot, 2011).

After introducing the describing and analyzing role of sciences in the transdisciplinary field of TPE with its important bridge function I would now like to illustrate how explorative studies may lead to insight and perspectives that may be used in policy making. When the now widely accepted approach of crop modeling had resulted in reliable crop models that could be used for exploratory studies, it became possible to guestimate which number of people could be fed without jeopardizing natural resources and safeguarding natural ecosystems (Rabbinge, The ecological background of food production, 1993).
The first, nearly back of the envelope, calculations of De Wit in 1966 suggested that an enormous number of people could be potentially fed, and suggested an extreme potential of planet earth (Alberda, Brouwer, & van Dobben, 1966). In a less extreme scenario making use of much more detailed soil data with the MOIRA model (Linneman, de Hoogh, & Keyzer, 1979), the step to bridging the gap between socioeconomic and biophysical modeling was made. That has resulted in an institutional arrangement, the Foundation for World Food Studies. Difficulties between disciplines caused less intensive collaboration during a long period, but the newly created Centre for Sustainable Development and Food Security at Wageningen University has been positioned to re-strengthen the ties. Studies into the world food situation require much commitment from professionals, because self-appointed specialists give modeling results which are nor realistic, nor scientifically sound. Now that food security and agricultural research is again top priority on the global research and policy agenda, advanced studies are urgently needed, both at global and regional level.

Studies at field-, cropping systems- and farming systems level have already demonstrated the large potential for productivity increase even in the Dutch situation and much more elsewhere. The computation of the sixtieth and seventieth of such improvements per ha at field level, per man hour and per animal have already become reality in some places.

Quantum leaps in eco-efficiency can be attained as demonstrated in experimental farms. The recoupling of animal and plant production be it at the farm or between farms, the decoupling of short term successes and at long term progress have been very successful. In dairy production Nitrogen use efficiency could be increased from 0.25 to 0.6 (Lantinga, Boele, & Rabbinge, (in prep.)). This illustrates the power of the combination of well-founded detailed process research, appropriate synthesis and integration, making use of models and their testing at farming systems level. Very promising, and very needed as Prof. Giller illustrates in his work in Africa. The renaissance of farming systems research with new methodologies, enriched insights

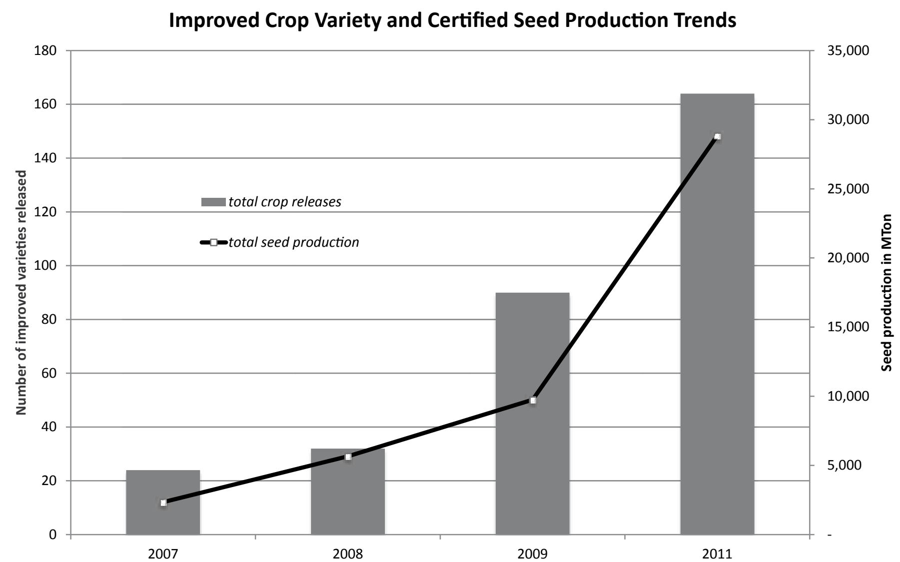

Figure 9 Improved crop varieties and certified seed production trends in Africa (Ngongi, 24-26 Oct. 2011)

and stronger unifying concepts can substantially contribute to the productivity rise of crops, cropping systems and farming systems (Fig. 9). Therefore the African green revolution where many more farming systems are prevailing than the rice-, wheat- or maize-dominated systems in Asia, requires a so-called rainbow evolution. This was propagated in the IAC study, 'Promise and Potential of African Agriculture' (InterAcademy Council, 2004).

That InterAcademy Council study, based on a painstaking analysis, laid the fundaments for AGRA. It explores and demonstrates the potential of African agriculture and makes clear that Africa, recently in a dreadful situation, is already changing dramatically and will continue to do so. A good enabling political environment and investment by public and private sector continues to lead to a situation where Africa contributes to world food security and is no longer seen as the hopeless continent, but as a major player in world food security.

The possibilities of agriculture in Europe were already illustrated in the study 'Ground for Choices' (Netherlands Scientific Council for Government Policy, 1992). In that study the societal goals adopted in documents at national and at European level were taken as a starting point. Social goals, economic goals, environmental goals, agricultural goals and nature goals were made explicit and with a multiple goals linear programming model different scenarios were explored. The basic data were based on the elementary concepts of Theoretical Production Ecology.
A quantitative and qualitative land evaluation demonstrated where which crop and farming system could operate, which yields are possible under various conditions (Fig. 10), and which technical coefficients may be used – the latter partly on the basis of the Delphi method using best ecological means as a principle (Rabbinge & van Latesteijn, Long-term options for land use in the European community, 1992). The results for the different scenarios were surprising at that time. The scenarios with different relative weights to the various goals varied in outcomes, but most staggering was the difference between the scenarios and the status quo, the reference scenario.

The pesticide use could be reduced by more than 70% (Fig. 11), the pollution with nitrate could be reduced by at least 50%, the costs could be 50% lower and the area in need for agriculture could be reduced considerably by at least 30%. This looked like utopia. This exploration study showed what is possible in principle. However, it was received as a prediction rather than an explorative study and therefore criterions like plausibility are incorrect; only consistency, logics and basic data should be sound. The Ground for Choices study did result in a lot of discussion and led to the wide recognition that European agriculture could be much more productive and cleaner.

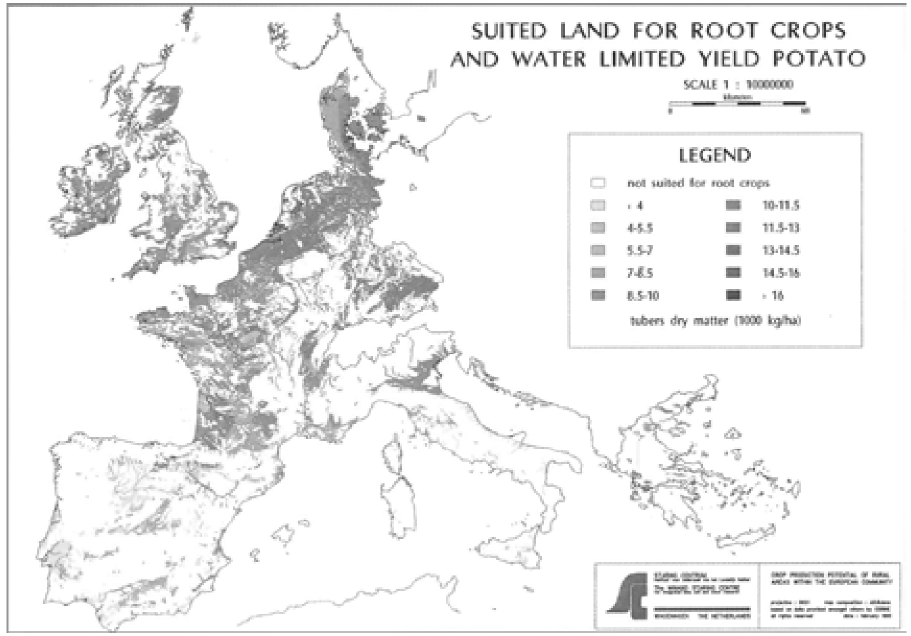

Figure 10 Explorative study on suitable land and yield levels for potato cultivation under water limitation within the European Community (Netherlands Scientific Council for Government Policy, 1992)

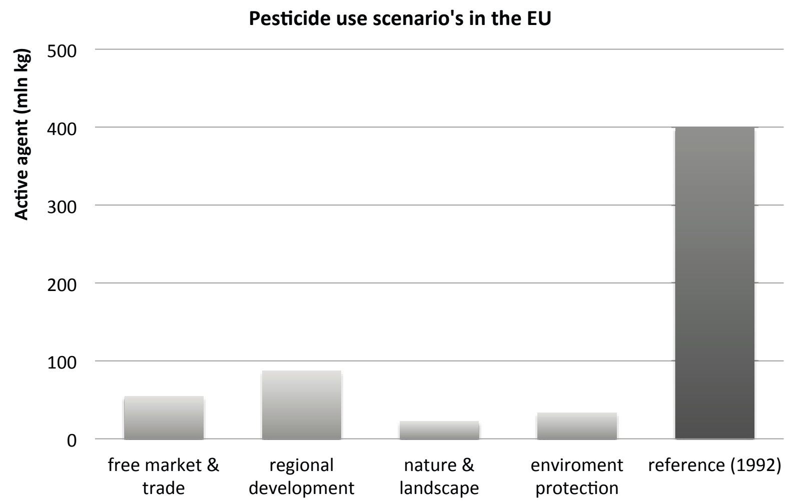

Figure 11 Explorative study on pesticide use in four different scenario's versus unchanged practices in 1992 (Netherlands Scientific Council for Government Policy, 1992)

A repetition of the study for Europe with 27 member states in the early years of this century demonstrated that the possibilities are even larger in this extended European Union.

Voluntary explorative studies are very often not acceptable to socio-economists that aim at prediction, thus closing the future instead of opening up (Fig. 12).

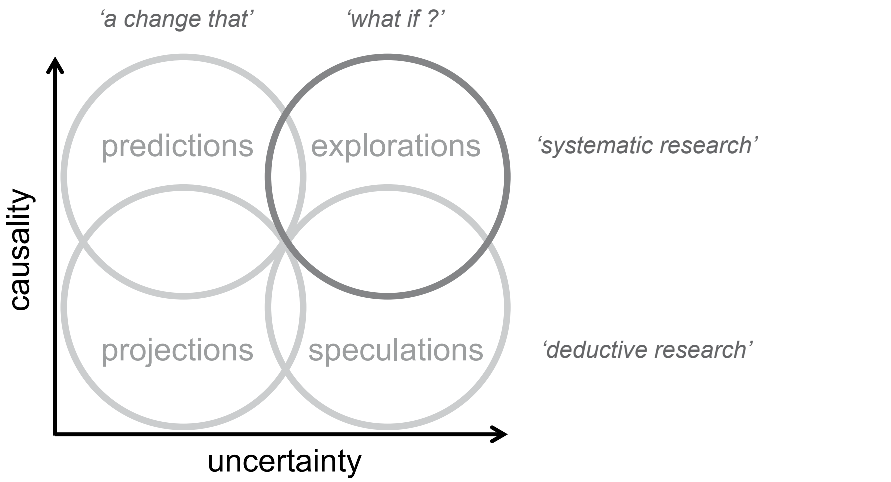

Figure 12 Typology of future research. If uncertainty in the system and model is apparent, `what-if' type questions can be addressed. If uncertainties are small, the probability of future events can be assessed. If causality of the model is prominent, more systematic future research is possible. If causality is lacking, only regressive or deductive methods are available leading to projections or speculations of future events (van Ittersum, Rabbinge, & van Latesteijn, Exploratory land use studies and their role in strategic policy making, 1998)

In the symposium before this farewell address four economists and one production ecologist (who happens to be the Rector) have contributed to the fact that I feel free to make clear that, in my opinion, there is an urgent need for more voluntary explorative approaches. I am pleased with the initiatives as described by Martin van Ittersum in his inaugural speech (van Ittersum, Future harvest, the fine line between myopia and utopia, 2011), as such initiatives are needed to stimulate perspective utopian thinking instead of doomsday dystopia thinking. Naive optimism is dangerous, but unjustified pessimism is discouraging and frustrating. Therefore realistic science-based explorative studies may help to see the boundaries, which is much more stimulating than doomsday thinking. Doomsday thinking comes back all the time and is also widely present in the western world and is in fact a repetition of Malthusian thinking.

It is very clear that during the last two centuries Malthus' thinking (Malthus, 1798) was different from the thinking proposed by the French philosopher and diplomat Condorcet a few years earlier (de Condorcet, 1796). He believed that human ingenuity would be able to meet the demands of a growing population and that humanity was not doomed to a cycle of famines and hunger, because human ingenuity would find different ways of producing (Fig. 13).

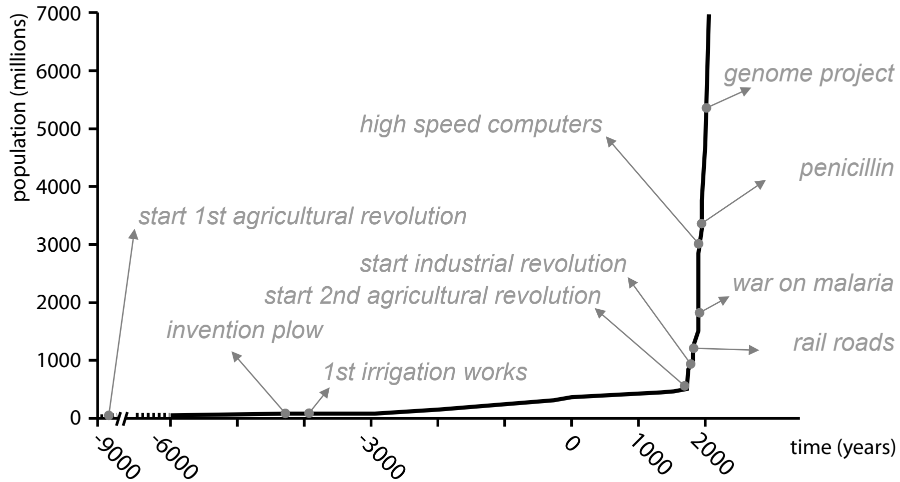

Figure 13 Unprecedented increase in world population since the last century and associated science-based developments. Adapted from (Fogel, 1999)

He did not deny the need or presence of upper limits but had much confidence in dramatic changes. He was right, for nobody could imagine, nor could Malthus at the beginning of the 19th century when there were about one billion people – now two hundred years ago – that at the present time, the beginning of the 21st century, 7 billion people would live in a world that is largely covering its need in production; neither could anybody imagine that per capita more food would be available than in 1800, although not accessible to everybody so that still a billion people go hungry because of bad politics, unbalanced production and bad distribution. A new abolitionist movement should stop this scandal for mankind. The symposium earlier this afternoon made clear what role science and policy have to fulfill. In fact we have to revisit many of the multilateral organizations, they have an enormous responsibility but fail at this moment. A revival of the Bretton Woods arrangements where stability in monetary terms, trade and development were central aims, needs reorientation and other stabilizing mechanisms on a world scale such as for example a global C-fund or other balance calculations are needed. That may lead to a revival of some UN organizations and institutions, pruning of outdated and creation of new multilateral organizations.

For the last 10 years I no longer had a chair at this University and my description until now has covered the period before my new assignment in 2001 to other responsibilities, among which that of University Professor for 1.5 days per week. I had the task to bring studies and teaching on sustainable development and food security to function.

In my inaugural address as University Professor, now about 10 years ago, I discussed the challenge to make sustainable development more than a container concept (Rabbinge, Sustainability and sustainable development, 2002). It is widely accepted that the three directives, more attention for the environment, more attention for future generations and more attention for a more balanced distribution over the world, should be taken into account for any action of man. More explicit definitions of sustainable development are senseless as in all cases more explicit normative political choices are needed. The political choices determine the boundaries, production structures and consumption patterns. It is for that reason that, as early as 1994, the study of the Netherlands Scientific Council for Government Policy developed the concept of action perspectives, through which political choices are made explicit; and it is transparent and clear where science-based politicizing ends and policies begin with normative choices (Netherlands Scientific Council for Government Policy, 1995). These perspectives were based on different perception of risks, acceptance of uncertainty and confidence in changes by adaptation of consumption patterns or production structures.

Four action perspectives: utilizing, saving, managing, caring, were made operational in the five domains where sustainable development requires specific choices. These five domains are food security, energy availability, conservation of natural resources and biodiversity and responsible use of water (Fig. 14). As sustainable development is a global concept according to the committee of the UN that coined the term in its report, 'Our common future' in 1987 (Brundtland, 1987), the domains are made operational at that scale. World food security, world energy supply and consumption, world use of natural resources including plant nutrients such as phosphate, world biodiversity and water supply and consumption are considered.

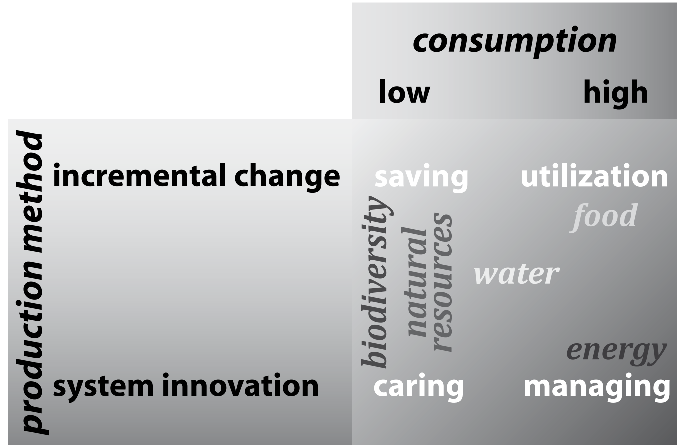

Figure 14 Four action perspectives, based on different perception of risks, acceptance of uncertainty and confidence in changes by adaptation of consumption patterns or production structures, show opportunities for resource use policies regarding sustainable development in five domains (Netherlands Scientific Council for Government Policy, 1995)

The choices concern the way of producing and the level of consumption. The scenarios developed on that basis were in some domains substantially different from the reference scenario that was more or less a trend extrapolation. For example in energy use the reference scenario shows an increase from 350 EJ in 1985 to1500 EJ in 2050. The majority of the growth is due to expansion of energy use in the developing world. In the scenarios, utilizing, saving, managing and caring, the total amount of energy use varied between 1200 and 700 EJ, substantially less than the reference scenario, but for the developed world this would mean a substantial reduction of energy use.
The reason for making these choices so explicit was to start a dialogue that is based on facts, challenges and concrete measures, rather than lip service or good intentions. In its report and in my inaugural address I made clear that it is very much needed for a society to make choices and that preconceived ideas, prejudices, dogmas, bans and myths are jeopardized and replaced by quantifiable and concrete action perspectives. The courses taught to a group of interested students during the last 6 years on food security and on sustainable development have made clear that not only the students

but also a wide group of faculty suffer from these preconceived ideas and dogmas. This is an attitude that is counterproductive for dialogue and discussion and detrimental for the practical application of sustainable development.

During the course the students came to the clear conclusion that choices are always needed and that, against their original belief and conviction, other choices were more in line with their intention. They became aware that in all cases optimization should be aimed at and maximization in one domain is unacceptable for others. The fact that the same attitude, for example caring, is not possible in all domains, was an eye opener. When caring is the action perspective chosen in natural resource management, much recycling and many other alternative sources are needed to prevent use of scarce (a subjective notion) resources, a similar attitude is therefore impossible in energy as much energy is required to achieve the recycling goal. In all the action perspectives these dilemmas occur and it is very necessary to make them explicit and a subject of debate. In its position vis-à-vis sustainable development the Council made clear that on the basis of reluctance to a considerable change in consumption pattern to lower food and energy consumption especially in the developing world, it would be wise to make ample use of new technology and in line with Condorcet's thinking of the ingenuity of man. Moreover, biodiversity and natural resources should be treated with much care because of the irreversible changes that may occur. Everyone will intuitively support that. Therefore the land area saved for nature and biodiversity should be maximized and the use of natural resources minimized. However, this implies that a similar attitude or action perspective is impossible in food security and energy. This leads to a mixture of action perspectives where the utilizing or saving scenario is chosen for food security, the caring scenario for natural resource management and biodiversity, for energy the saving and for water the managing perspective. In that way a combination is chosen that is coherent, feasible and doable. However, it is an academic exercise with only a few followers. It is difficult or nearly impossible to have such a comprehensive cohesive concept for sustainable development. Nevertheless it is important that the discussion is continued, and strengthening of thinking in action perspectives, modalities and choices is attained. Next year Rio+20 will be organized and it would be very rewarding and stimulating if the discussion is oriented to these upgraded and updated perspectives translated in concrete action rather than the discussion on REDD+ or unrealistic figures on greenhouse gas emission. Sustainable development is much more than climate change and has much to offer for the scientific community to develop perspectives, for the private sector to renew the societal contract to produce and to deliver, and for the public sector to reinvent the role as facilitator, stimulator, catalyst and enabler rather than a rigid regulator with continuous trust in the fallacy of misplaced concreteness by the introduction of wrong indicators or by the stimulation of perverse subsidies and mandatory regulation.
During the last four years we have seen much leadership in sustainable development in the private sector, especially the food industry. Large food industries like Unilever and Nestlé have introduced serious programs on sustainable supply chains. An exact definition and description of sustainable development is absent and not needed as the direction of change and improved efficacy and efficiency and integrated chains and lateral connections are needed in all cases. After a period of tolerance for a group in the company working on these concepts, a period of acceptance and then respect and finally pride has followed. The sustainable supply chain is no longer a small part of the business but mainstream activity. In fact, the companies in the food and feed industry including all Dutch cooperatives take sustainable development seriously and do not longer see it as PR but as a mainframe activity. That is also very clear in the experience of Transforum during the last 5 years. The program has initiated, stimulated and managed several programs where corporations and knowledge institutes have developed new ways of producing and new products, which are serving specific aims in all domains. It became clear that only if the research and innovation by knowledge was in tandem from the beginning, successful projects and programs could be achieved. Programs dominated by the corporations or by the knowledge institutes were seldom successful. It illustrates the need for intermediate structures that catalyze such innovations and are successful in bringing parties together and identify the appropriate research questions. That is needed as wicked problems, normal in sustainable development, requires such an iterative research approach. This way of reorienting the knowledge infrastructure, especially in the food and agribusiness industry, is in line with a historic trend that competitive ability is based on first mover behavior in innovation. That requires programs and intermediate structures such as recently developed in the Carbohydrate Competence Center (CCC), Biosolar cells and the Netherlands Genomics Initiative (NGI) centers. It would be wise to use the scarce public means for innovation in these centers with a proven track record rather than financing some hobbyhorses of the big players in the energy sector.

In the foregoing I have tried to make clear that, on the basis of deepening insight in the functioning of biological systems, we have something to offer. Perspectives for a food secure world, regions and continents with much less pollution, erosion and other unsustainability threats are possible; and energy systems that are very different from the present mega scale production units can be made operational in due course (Fig. 15). The energy producing glasshouse will become operational in the coming years, energy neutral buildings are possible within a limited time, energy systems dominated by small scale biosolar generation connected through networks are possible. Leapfrogging to these new systems may be the way to go. The world can safeguard both agro-biodiversity and save land area for nature if the highly-productive agriculture using production ecological principles is done at the right place. Water can be used much more efficiently and natural resources can be used with care. The historic trends in productivity, the still enormous possibilities and the increasing political will and new institutions justify this optimism. Scientific analysis, fundamental or applied, lays the basis for such possibilities and that is very important in the very vulnerable relation between science and policy.

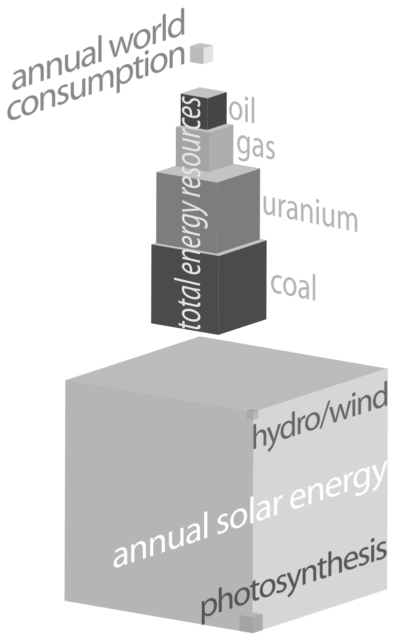

Figure 15 The annual (!) amount of solar energy reaching the earth is substantially larger than the overall reserves of fossil energy combined. Adapted from (Lomborg, 2001)

It requires right investments, and doomsday thinking should be history. Food security, energy safety, water availability, biodiversity maintenance and natural resources are possible, not all maximally but in an optimal way if the right choices are made. At present, however, policies on biofuel (obligatory mixing), subsidies on inefficient ways of production and restrictions in innovation funds or cuts in scientific budgets are still more characteristic for the prevailing policy than the age of enlightenment that brings utopia near.

During my whole career I have been involved in international agricultural research by assignments in Berkeley, Melbourne, Leuven and many smaller obligations in various countries of Asia and Africa. But my activities in the CGIAR were most intensive, especially during the last decades when I had responsibilities in centers and chaired the Science Council. A very interesting and rewarding assignment and I am pleased that so many friends of the CGIAR family are here today. I have been heavily involved in the change of the CGIAR and the renewal of the structure and responsibility in the organization – a change similar to the creation of WUR in the second half of the nineties. I am convinced that the new structure, if pruned considerably in the coming years (there are too many management units and CRSP's) will be much more attractive for outside partners, knowledge institutes such as CAAS, Embrapa, ICAR, INRA/CIRAD, Land grant Universities in the USA and WUR, but also many private sector companies. The role the CGIAR can play as a broker as focal point and as the place where genetic material is stored and available and knowledge is concentrated, is vital for international agricultural research. The revival of agricultural research and the renaissance of broadened research on food systems and non-food systems is crucial for food security: management of natural resources and safeguarding biodiversity. That role can be played by the CGIAR and it is in the mutual interest of organizations such as WUR to strengthen these ties.

When I delivered my first speech in this auditorium, now 43 years ago, at the occasion of the 61st almanac of CERES, I gave an optimistic view on the evolution of man and the critical role of democracy in line with the thinking of the sixties of the last century (Rabbinge, Alamanakrede (69), 1969). I presented a plea for more external and internal democracy based on the criterion that democracy is in fact organized and delegated confidence rather than just populist vote. On that occasion the then secretary of the academic senate of the University, Professor Visser, responded with a plea for the Swiss system of democracy where a substantial number of decisions were on the ballot with regular elections or referenda. I made clear that I was not in favor of such forms of democracy. It will lead to unbalanced decisions and overruling by one-issue movements. The one-issue movements and much conservatism based on badly understood self-interest have a function to make a particular point clear, but in a complicated society a balanced decision process requires responsible policy makers, transparent, explicit and well-argued decisions at all aggregation levels or jurisdictions. It is striking to see that the growth to internal democracy in organizations such as universities, introduced in the seventies, did not continue because of lack of balance between commitment and responsibility and the difficulty to work in a monistic system, as many still look at it as a dualistic system.

The need to work in a society and improve decision-making was key in my functioning on the stimulating fringe of science and society. I was pleased to see much progress in the quality of decision-making at many places and disappointed to see that during the last decade not democracy as such was improved but populist movements increased in power and interest.
The role of science is then also limited, because not analysis, rich diagnosis and well-reasoned and argued options dominate, but opinions, prejudices and pre-conceived ideas. That is a danger in external democracy but also in internal democracy such as in the university. That is in fact a good place to improve and learn democratic attitudes and functioning.

The strong interest of students in societal goals such as food security and sustainable development is, however, stimulating and encouraging. A new generation of scientists has already started to revitalize the functioning of democracies, maybe in a different way from before, but the new media as easy means of communication will lead to new democratic mechanisms. See what happened in parts of the developing world, a new Arab/African spring, and that is very different from populist movements.

A new abolitionist movement, for eradication of hunger and in support of food security, created and strengthened, is bundling the interested and committed scientific community to contribute to the most important problem of the first two decades of this century, MDG1, abolishment of hunger and poverty. The role of science is of crucial importance. That is based on the various roles scientists may play and it was an honor and a privilege to contribute to this honorable task for such a long period.

During my longstanding position at Wageningen University I have been fortunate to work in an executive capacity at chair group, sector, department, graduate school(s) and in the position of University Professor. In all positions I was crucially supported by many who collaborated with me. The erstwhile Theoretical Production Ecology chair group, the department and sector Plant and Crop Sciences and the graduate school on Production Ecology and Resource Conservation, Wageningen Graduate Schools and in the last phase the Centre for Sustainable Development & Food Security, have all been places which have achieved great scientific progress and have contributed to solving society problems and to deepening scientific insights. I have had splendid collaborators including especially secretaries, and as a professor in different fields 4 excellent successors and many, many stimulating MSc students and PhD's. That is a luxury more than money can buy. It was an enrichment for my life and I like to thank you all for that.

I know that it is impossible to mention all that have played such an important role during that long period. Therefore I will limit myself to three persons that were crucial in the three phases I distinguish. I would like to mention Jan Goudriaan, Jan Schoonenboom and Maja Slingerland.
Jan Goudriaan, you've been the scientific drive in my period at Crop Ecology and TPE. Jan Schoonenboom, you've made my life at WRR the best period of my scientific career, and Maja, you've made the creation of the Centre for Sustainable Development & Food Security a success through your painstaking committed course and training work.

Finally, although she finds this embarrassing, I would like to thank my wonderful wife Marja. She has made all this possible and has succeeded in creating a family with children and grandchildren that is committed and cohesive and with mutual respect and love. That is the sound basis for anyone who would like to function in such a demanding job.

Ladies and gentlemen, it has been an honor to function at this world-leading knowledge institute for such a long period and I would like to thank you all for attending this farewell address. With this I give the floor to the Rector Magnificus.

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Rudy Rabbinge

Agricultural production in the world, and especially in the Netherlands, is higher, better and cleaner now than 10 years ago. Less acreage is needed, which is better utilized, leaving more land to nature. Impact to the environment is also notably less.

Future scientific developments warrant sufficient food availability for a growing global population. However, bad policies, uneven production, inequality of access to food presently still leave one billion people in starvation. That is unacceptable for humankind and can and should be changed.

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